PROJECT FACT SHEET

CONTRACT TITLE: Imaging, Modeling, Measurement and Scaling of Multiphase Flow Processes

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PROJECT SITE **CITY:** Berkeley **STATE:** CA **CITY:** **STATE:** **CITY:** **STATE:**	**CONTRACT PERFORMANCE PERIOD:** 2/15/1999 to 2/14/2000 **PROGRAM:** Supporting Research **RESEARCH AREA:** Partnership/Drilling & Completion **PRODUCT LINE:** ADIS

FUNDING (1000'S)	DOE	CONTRACTOR	TOTAL
PRIOR FISCAL YRS	0	0	0
FISCAL YR 1999	200	0	200
FUTURE FUNDS	0	0	0
TOTAL EST'D FUNDS	200	0	200

OBJECTIVE: Develop methodologies based on advanced imaging technology or rapid and accurate measurement of petrophysical properties and prediction of engineering parameters needed for reservoir simulation.

PROJECT DESCRIPTION:

Background: This project supports reservoir description and advanced oil recovery processes research based on the understanding of fundamental rock-fluid interactions at the micro- and macroscopic scale (pore to whole core scales) by developing and applying cross-cutting imaging techniques and technologies.

To simulate multiphase flow in a reservoir, one needs to know, for the various facies, petrophysical parameters, such as porosity, permeability, two and three phase relative permeabilities, capillary pressures under drainage and imbibition, distribution of wetting properties, residual oil and water saturation, formation volume factors, etc. However, laboratory measurements of these parameters using core plugs are expensive, time consuming, often subject to differing interpretations and, in some cases, virtually unavailable (eq. three phase relative permeability). Thus, the industry has shown significant interest in using methods and approaches which require a minimum of core material to determine these parameters. One very promising approach uses pore network models to compute rock properties.

The goal of this program is to provide new methodologies for bridging the gap between available laboratory (and borehole log) data and field scale permeterization required for reservoir simulation. To achieve this goal, imaging technologies, including linear X-Ray and CT imaging, Microfocus X-Ray imaging, NMR microscopy and Low field NMR relaxometry, Probe Minipermeametry, Petrographic image analysis (PIA) and Mercury porosimetry will be combined with direct laboratory flow measurements and numerical simulations using the wavelet transform upscaling approach which has been shown by simulations and experiments to be robust, flexible and accurate. Upscaling is a process for calculating representative rock properties for the minimum scale required to reliably predict the flow performance in a reservoir by using the properties that are measured at smaller scales. Upscaling is critical in translating parameters measured from laboratory core plug samples into values representative of the much larger grid blocks used in field simulators while preserving to the greatest possible extent the effect of the complex geological heterogeneities that exist in fine scale geological reservoir modes.

Work to be Performed: 1) Development of wavelet based upscaling. The analysis of the wavelet upscaling for the single phase will be completed and a paper will be prepared for presentation and/or publication. The study of applicability of wavelet upscaling to two and three phase flow will be initiated. 2) Installation of the rock-fluid imaging laboratory; to perform the lab flow measurements needed to validate upscaling and pore network models, a new laboratory will be designed and constructed to accommodate the following equipment - X-Ray CT, High and Low Field NMR, Linear X-Ray Scanner, Probe Minipermeameter, Beckman Ultracentrifuge and PIA apparatus. 3) Analysis of high resolution pore scale images; pore images collected under another DOE project will be converted to a pore network using newly available processing algorithms and extracting the pore parameters needed for simulations of single and multiphase flow. A literature review will be performed to evaluate the state-of-the-art understanding of multi-phase flow through porous media at pore to core level and to identify the influences of fluid-fluid and rock-fluid interactions on the flow dynamics in rocks.

In the following fiscal year, based on the findings of the review, such interactions will be incorporated into the network multiphase mathematical model and coded into appropriate software. Experiments will be designed and performed to verify the model. CT imaging and/or linear scanning of samples under single phase flow (tracer tests) and two and three phase flow (steady and unsteady state) will be performed. Scaling relationships will be sought between high resolution pore scale flow results and lower resolution X-ray plug measurement results. From the imaging studies using tracers, the analysis of dispersion will be evaluated as a tool to infer pore scale properties. To complement the X-ray CT upscaling studies, and to provide data needed for improved interpretation of NMR logs, low field NMR measurements will also be performed. A particular focus will be on NMR measurements at reservoir conditions.

PROJECT STATUS:

Current Work: Task 1: Initiate a rock type database for pore network modeling. Calibrating the pore network model against a variety of rock types is necessary before the network modeling can be used with confidence in rapid prediction of petrophysical properties in an exploration and production (E&P) environment. Complete petrophysical and pore data for various rock types will be obtained from our lab measurements, literature and from industry. Oil companies and oil service companies will be contacted for core samples and data.

Task 2: Measure petrophysical parameters of selected rock samples. Permeability, porosity, relative permeability and capillary pressure curves will be measured. As the first step, two water wet sandstone samples will be measured. In subsequent stages, mixed wet and oil wet samples including carbonates will be selected. Measurements will be performed for both drainage and imbibition processes. The use of the low field NMR relaxometry as a potential source of pore data will be investigated. Any progress in this area can be of immediate use to industry through improvements in NMR logging protocols.

Task 3: Develop methodology for rapid extraction of pore parameters for network models. Work will emphasize the streamlining of the image analysis process for extracting the pore data needed for network modeling. Based on the work performed in the previous year the goal will be that by reducing the time it takes to analyze the pore data, a larger number of rock samples can be studied and their pore network modeled. Three dimensional pore network models will be generated for the selected samples.

Task 4: Study of wavelet upscaling for two phase flow. CT imaging and simulation will be used to investigate the applicability of wavelet upscaling to sample exhibiting high contrast heterogeneity.

Scheduled Milestones:

Complete methodology for rapid extraction of pore parameters	06/00
Complete set of petrophysical and pore data for network modeling for two rock samples	08/00
Report on Status of Rock Type Database for Pore Network Modeling	09/00

Accomplishments: Completed installation of new Rock-Fluid Imaging Laboratory consisting of: - Siemans Somatom HiQ X-Ray CT apparatus; - JEOL high field NMR Microscopy apparatus; - Resonance Instruments low field NMR apparatus; - Beckman Ultracentrifuge; - Linear X-ray scanner; - Probe Minipermeameter.

Coauthored paper titled; "Multiscale Heterogeneity Characterization of Tidal Channel, Tidal Delta, and Foreshore Facies, Almond Formation Outcrops, Rock Springs Uplift, Wyoming", by R.A. Schatzinger and L. Tomutsa, in R. Scahtzinbger and J. Jordan, eds. Reservoir Characterization-Recent Advances, AAPG Memoir 71, p45-56.

Used network analysis software package 3DMA from SUNY to extract pore network parameters from Micro CT images of Saltwash sandstone sample.